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A Study of Drouth Resistance in Inbred Strains of Sweet Corn *Zea Mays* Var. Rugosa

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SUMMARY AND CONCLUSIONS

Of the anatomical and physical properties studied, i.e., transpiration, number of stomata, root system and vascular bundles, none offers a means of classifying unknown pure lines or strains into resistant or susceptible classes. All may play a part in enabling the plant to withstand periods of high temperature and drouth. Several other factors, not studied, may also play a part, such as the colloidal properties of the leaf tissue as suggested by Newton and Martin (18) and higher osmotic value in the roots of drouth resistant plants as suggested by Hedgecock (4).

Results of these studies may be summarized as follows:

1. Sweet corn plants of pure lines, which had been classified as drouth and heat susceptible or resistant, were studied to determine if certain anatomical or physical characters were correlated with resistance or susceptibility. A character associated with resistance or susceptibility could be used to study pure lines of unknown ability to withstand drouth and heat by laboratory methods if a succession of favorable growing years made such classification impossible in the field.

2. The transpiration rate of inbred lines of sweet corn was higher with susceptible inbreds as a group than with resistant lines under conditions of high temperature and low relative humidity.

This could not be used, however, as a basis of classification, because the difference was not of sufficient magnitude.

3. No significant differences in numbers of stomata on lower and upper surfaces of the leaves of resistant and susceptible inbred lines were obtained.

4. The volume of roots may account for susceptibility of several lines, but no significant differences occurred between the weights of roots of the two classes when grouped together.

5. The number of nodes below the surface of the soil in the two classes of inbreds did not differ when the two classes were averaged.

6. The total number of vascular bundles in the stalks depends on the diameter of the stalk, stalks of larger diameter, within a given line, having more bundles than stalks of smaller diameter. The average number of bundles per unit area is a fairer comparison, but in sweet corn inbred lines, the resistant and susceptible classes do not differ significantly in this respect. A comparison of a limited number of resistant and susceptible inbred field corn lines showed a significant difference, the susceptible class having more bundles per unit area of cross-section.

7. A satisfactory laboratory test, for classifying the lines into resistant and susceptible classes, has been made by exposing 15 20-day-old seedlings to high temperature and low humidity. Exposure at 55°C (131°F) for 5 hours caused the death of most of the susceptible seedlings. Some resistant plants of sweet corn survived a temperature of 55°C for 6 hours.

8. Field corn inbred lines classified as resistant endured a higher temperature for a longer period of time than resistant sweet corn lines.

ERRATUM

The varietal name, *Rugosa,* in the title of this bulletin should be in italic face type.

A Study of Drouth Resistance in Inbred Strains of Sweet Corn *Zea Mays* Var. Rugosa [1]

By E. S. Haber[2]

Plant breeders have noted that corn inbreds and hybrids show marked differences in their ability to withstand even mild periods of drouth and high temperatures. Sweet corn inbreds and hybrids as a group do not have as high resistance as field corn inbreds and hybrids. The most resistant sweet corn lines are not equal to the most resistant field corn lines.

Since 1929, in central Iowa, it has been comparatively easy to classify sweet corn inbreds in the field according to their relative resistance. Less than normal rainfall and higher than normal temperatures during a part of the growing season each year have made possible the classification of the lines into one or more of the following four groups: Those which are subject to (a) tassel firing, (b) firing of the top two or three leaves, (c) firing of the lowest three or four leaves and (d) excessive rolling and wilting of the leaves. Plants of lines which are classed in group (d) roll their leaves during periods of high temperature and drouth to the extent that the leaves may fail to unroll entirely when conditions are more favorable. Stunting or death may result.

Production and release of inbred lines to commercial producers of hybrids during a series of years very favorable for the growth of corn may result in the distribution of lines not resistant to short periods of drouth. During favorable years susceptible lines do not have a chance to manifest themselves to the breeder. The present study was made to determine if there were any physical or anatomical characters of pure lines associated with resistance or susceptibility to drouth and high temperature, so that lines could be tested by laboratory methods during cycles of favorable growing years.

REVIEW OF LITERATURE

Kiesselbach (9) found no difference in the average water requirement per pound of dry matter of four varieties of corn, two of which were acclimated to humid climate and two to relatively dry conditions. Further, he found that several so-called drouth resistant varieties possessed practically the same water requirements per

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[1]Project 470 of the Iowa Agricultural Experiment Station.

[2]The author is indebted to Prof. George W. Snedecor of the Statistical Laboratory for advice and assistance with analysis of variance of the data.

pound of dry matter as the average of 11 other varieties. He concluded that drouth resistance of certain crops was not associated with a low water requirement per pound of dry matter.

Maximov (14) and Maliboga (16) showed that the same degree of wilting due to moisture deficiency may affect cereal plants differently at different stages of growth. During rapid elongation of stems and formation of flowers wilting caused stunting, while earlier, and again after flowering, the effect was insignificant. Hunter, Laude and Brunson (8) tested the resistance of inbred field corn lines by placing 14-day-old seedlings in a 140°F chamber for 6.5 hours. Lines exhibiting high relative resistance to injury from drouth and high temperature survived after removal from the chamber, whereas susceptible lines died.

Aamodt (1) demonstrated for wheat varieties differential resistance paralleling that observed in the field under conditions of severe drouth by exposing the plants in a wind tunnel to 110°F and a 6-mile per hour wind. Shirley (19) studied drouth resistance of white spruce, *Picea canadensis,* in an illuminated, temperature-controlled chamber. The entering air stream was passed over calcium chloride to dehydrate it; the length of time of survival was used as a measure of the drouth resistance of each plant.

When discarding lines because of susceptibility to heat and drouth injury the work of Loomis (12) should be taken into consideration. When the leaves were removed at tasseling, the upper leaves were significantly more efficient in grain production than the lower until 75 percent of the area was left. Since firing frequently occurs at or near the tasseling stage, pure lines which top-fire may produce significantly less grain.

MATERIALS AND METHODS

Inbred lines of sweet corn developed by the Vegetable Crops Subsection of the Iowa Agricultural Experiment Station, with the addition of several field corn inbred lines furnished by the Agronomy Department, were used for these studies. The lines ranged in reaction to heat and drouth from resistant to susceptible under field conditions. For most of the studies, only those exhibiting extreme resistance or susceptibility were used. Susceptible lines used were those exhibiting much leaf firing, either basal or top leaves, and those the leaves of which were extremely rolled, with a resultant stunting and high mortality.

TRANSPIRATION

Plants of several resistant and susceptible lines were grown in gallon jars in the greenhouse. When the plants were tasseling the soil was allowed to dry so that the plants wilted slightly on bright clear days. The transpiration rate of the leaves of these plants for

TABLE 1. TRANSPIRATION RATE OF CERTAIN INBRED LINES OF SWEET CORN AS MEASURED BY ABSORPTION WITH CALCIUM CHLORIDE.

Resistant inbreds	Grams of water absorbed by $CaCl_2$	Susceptible inbreds	Grams of water absorbed by $CaCl_2$
191	.2059	1448	.2834
123	.2109	1627	.1888
777	.1878	1608	.3172
908	.2889	1607	.3465
1612	.3028	1572	.2950
1434	.2679	1429	.2531
Mean	.2440		.2807

Analysis of variance of transpiration rate

Source of variation	Degrees of freedom	Mean square
Resistant vs. susceptible	1	.00805
Inbreds in groups	10	.00537**
Plants of same inbred	12	.00009
Total	23	

**Highly significant

a 24-hour period was measured by a method described by Heinicke (5). A glass weighing bottle fitted with a rubber gasket and containing 1 to 2 grams of calcium chloride was clamped to the leaf. The amount of water absorbed by the calcium chloride was accurately weighed on a sensitive balance. Results are presented in table 1. The figure given for each inbred line is the average of two to four readings. Analysis of variance indicates that the means for the two groups do not differ significantly. The rate of transpiration under unfavorable conditions was higher in the susceptible inbreds when grouped than in the group of resistant inbreds. There was more variation, however, between the lines in a group than between groups.

Transpiration rate under similar conditions as outlined above was also tested by means of the hygrometric paper method of Livingston and Shive (10). Cobalt chloride paper was placed on the leaves between glass slides held with a clip. Color standards were also included in the clip in order to determine the end-point. The time required for the cobalt chloride to change from blue to pink was measured with a stop watch.

Since temperature affects the transpiration rate the average time for color change was corrected to 20°C to make all readings comparable (table 2). Several hours may have elapsed between the first and last readings taken on different inbreds, and the air temperature may have fluctuated and changed the rate of transpiration. The transpiration rate was faster and easier to measure on the lower surface of the leaves than on the upper surface. When the transpiration rate is very slow, it is difficult to determine the end-point of the color change. Two to three readings were made on each leaf and four leaves were used on each plant; four plants of each inbred were used.

TABLE 2. TRANSPIRATION RATE OF CERTAIN INBRED LINES OF SWEET CORN AS MEASURED BY COBALT CHLORIDE PAPER COLOR CHANGE.

Resistant inbreds	Time period (seconds) to change color	Susceptible inbreds	Time period (seconds) to change color
191	43	1608	22
777	44	1126	24
1284	42	701	33
123	35	1214	33
		1126	28
Mean	41	Mean	28

Analysis of variance of transpiration rate

Source of variation	Degrees of freedom	Mean square
Resistant vs. susceptible	1	2300.13**
Inbreds in groups	8	54.66
Plants of same inbred	35	30.08
Total	44	

**Highly significant

Examination of the analysis of variance for the transpiration rates of the resistant and susceptible groups shows a significant difference between the means of the two groups of inbreds. The transpiration rate was faster with the susceptible lines.

This study of the transpiration rate of known resistant and susceptible inbreds revealed that when tested with hygroscopic paper the rate of transpiration under less favorable conditions was higher for the susceptible group than the resistant. When tested by the calcium chloride method, although the mean transpiration rate of the susceptible lines was greater than that of the resistant lines, the mean difference was not significant.

STOMATA

The stomata are regarded as the principal plant agency affecting the transpiration rate. Water lost through other parts of the plant, cuticle, etc., is insignificant compared with the loss through the stomata.

To determine the number of stomata on the upper and lower surfaces of the leaves, resistant and susceptible lines were grown in the greenhouse in gallon stone jars under dry soil conditions. When the plants were tasseling, leaf impressions were made by using films of celloidin. Twenty-four grams of cellulose acetate were dissolved in 150 c.c. of ether and 50 c.c. of absolute alcohol.

With a 1-inch brush, a strip of the solution about 1 inch wide and 4 or 5 inches long was painted on the center of the leaf. In about 2 minutes, when the solution had hardened sufficiently, it was pulled off with forceps. When the film was stripped from the leaf it was placed between two glass slides which were taped together. This was done to prevent too much shrivelling and wrinkling of the film, an effect which occurred when the film was exposed to the air for several weeks. Impressions were made of the lower and upper surfaces, about the center of the leaf, of leaves from the second to the sixth node, on two plants in each inbred strain. The film impressions were filed until microscopic counts could be made. Results are presented in table 3.

Although there was a significant difference between the numbers of stomata on the upper and lower sides of the leaf, the two groups, resistant and susceptible, did not differ significantly. Lloyd (11) states that the rate of transpiration may undergo sudden and wide changes without the accompaniment of a sufficient alteration in the dimensions of the stomata to account for the changes by the theory of stomatal regulation of transpiration and that changes of relative humidity were not correlated with regulation of transpiration by changes in stomata. Since the data show little differences in number of stomata between resistant and susceptible lines, numbers cannot account for the degree of resistance to high temperature and drouth (table 3).

Although Hull (7) reported that seedlings of inbred strains of field corn showed marked differences in the number of stomata

TABLE 3. NUMBER OF STOMATA PER SQUARE MILLIMETER LEAF SURFACE IN RESISTANT AND SUSCEPTIBLE LINES OF SWEET CORN.

Resistant	Leaf 4		Leaf 5		Leaf 6		Leaf 7		Leaf 8		Mean	
inbreds	*U	L*	U	L	U	L	U	L	U	L	U	L
191	42	66	50	75	60	78	62	80	61	79	55	76
777	45	65	45	71	58	71	42	75	42	77	46	72
261	44	74	34	58	46	68	43	73	56	69	56	68
1445	29	58	33	69	35	56	36	56	41	58	35	59
853	45	65	52	63	57	60	50	73	47	60	50	64
Mean	41	65	43	67	51	67	47	72	48	69		
Susceptible inbreds												
157	57	79	53	76	47	74	49	74	49	80	51	77
1126	43	65	51	67	39	71	39	71	33	68	41	68
1071	48	77	48	71	44	75	40	70	42	78	44	74
1572	44	65	43	81	40	62	41	62	41	83	42	71
900	36	58	32	50	32	52	32	50	32	49	33	52
Mean	45	69	46	69	41	67	40	66	40	71		

*U — upper surface of the leaf
*L — lower surface of the leaf

Analysis of variance of upper surface

Source of variation	Degrees of freedom	Mean square
Resistant vs. susceptible	1	124.82
Leaf	4	15.73
(R. vs. S.) x leaf	4	141.27
Within group	40	335.01
Total	49	

Analysis of variance of lower surface

Source of variation	Degrees of freedom	Mean square
Resistant vs. susceptible	1	524.88
Leaf	4	73.73
(R. vs. S.) x leaf	4	90.63
Within group	40	568.64
Total	49	

per unit area of leaf surface, the sweet corn inbreds used in this study showed remarkable consistency when examined at the tasseling stage for number of stomata per unit area. The number of stomata is less at the basal and center portion of the leaf than at or near the tip, so that in comparing the different lines it was necessary to count the stomata located at the same relative position on the leaves. Size and shape were remarkably constant in most of the lines, except inbred 900 which had guard cells smaller than those of other Country Gentleman inbred lines.

During the summer of 1937, which was a favorable year at Ames for the growth of inbred sweet corn lines, three lines showed distinct firing of the leaves about Aug. 1. Celloidin film impressions of the fired leaves were made in the field to determine whether the stomata number differed from the normal green leaves of the same plant and whether they differed from plants exhibiting no firing. One strain, 1627, had lower leaves severely fired, and 2306 had the upper three or four leaves fired. All plants in each of these two lines showed firing. The number of stomata of fired and normal leaves is presented in table 4.

The differences in number of stomata on lower and upper surfaces of the fired and non-fired leaves of susceptible lines were not great enough to account for the firing of certain leaves. The differences in number of stomata between leaves of non-fired plants and fired leaves of susceptible plants do not differ sufficiently to account for the firing.

According to Weatherwax (20) groups of hydrophilic cells in the upper epidermis are gorged with water under favorable conditions, but when conditions become less favorable and the transpiration rate increases excessively, these cells shrink through loss of water; this shortens the epidermis on the upper side, which causes the leaf to roll. Rolling protects the upper epidermis from the air, as well as a part of the lower epidermis in extreme rolling. He suggests that this behavior may be quite as effective as the stomata in regulating the loss of moisture. One should, on this basis, expect greater resistance in pure lines if rolling is common to that line. However, several susceptible lines reported herein, especially 1607, 1608 and 1804, evidence extreme rolling under conditions of reduced moisture supply and high temperature.

TABLE 4. NUMBER OF STOMATA ON FIRED AND NORMAL LEAVES OF DROUTH RESISTANT AND SUSCEPTIBLE LINES OF SWEET CORN.

	N* 1445	N* 1612	T** 2306	B*** 1627
Upper leaf — Top	81	118	94	97
Upper leaf — Bottom	99	124	116	120
Lower leaf — Top	83	95	75	90
Lower leaf — Bottom	98	116	98	106

*N, no firing
**T, top-firing
***B, bottom-firing

Counts of stomata gave no basis for classifying pure lines of unknown behavior as resistant or susceptible. No comparative measurements were made of stomatal apertures, because the author was trying to find a character associated with resistance which could be determined rapidly. The use of the celloidin film for counting numbers of stomata is fairly rapid but not suitable for measuring stomatal apertures.

ROOTS

With a shortage of water in the soil one might expect the type and extent of the root system of the plant to influence the amount of water absorbed. Since "pure lines" exhibit marked differences in extent and depth of root system, one might expect the lines with deep and fibrous roots to withstand more drouth than lines with shallow, coarse root systems.

Individual plants of resistant and susceptible lines were grown in gallon stone jars in the green house under favorable conditions. When the plants were 8 weeks of age, they were removed from the jars, the roots were washed free of soil, surface dried with cheesecloth and dissected from the plant. At 8 weeks, the plants were not yet pot-bound. The roots of each plant arbitrarily were divided into two classes, coarse roots and fine hairy roots; roots ⅛ inch or more in diameter were classified as coarse. Individual weights for each of the 74 plants were recorded. Data are summarized in table 5.

No significant differences between weights of roots of susceptible and resistant lines occurred to account for differences in their ability to withstand drouth. It would be expected that the extent

TABLE 5. WEIGHT OF ROOTS OF CORN PLANTS RESISTANT AND SUSCEPTIBLE TO DROUTH AT 8 WEEKS OF AGE.

Susceptible				Resistant			
Inbreds	Total wt. of roots	Wt. of hairy roots	Wt. of coarse roots	Inbreds	Total wt. of roots	Wt. of hairy roots	Wt. of coarse roots
1572	5.74	1.82	3.92	1612	3.99	1.47	2.52
157	1.97	0.76	1.21	1621	4.19	1.88	2.31
701	5.11	1.52	3.59	1445	3.06	0.95	2.11
900	3.62	1.40	2.22	261	2.23	1.05	1.18
1214	3.48	1.51	1.97	853	3.92	2.40	1.52
1126	1.79	0.44	1.35	908	4.11	1.68	2.43
1071	4.04	1.27	2.77	191	2.60	0.48	2.12
1627	3.70	1.74	1.96	777	4.03	1.94	2.09
1608	4.65	1.70	2.95	12E	2.88	1.11	1.77
1448	4.97	2.37	2.60	B164	4.15	1.55	2.60
Ave.	3.89	1.42	2.46	Ave.	3.51	1.45	2.06

Analysis of variance of total root weight

Source of variation	Degrees of freedom	Mean square
Resistant vs. susceptible	1	.0364
Varieties of same group	19	1.0483
Plants of same variety	53	.2451
Total	73	

and character of the root system would influence the ability of the plant to absorb moisture. Briggs and Shantz (2) point out that plants with coarse, scantily branched root systems leave more water in the soil than do plants, such as the grasses, with more branching root systems. Miller's (15) studies on the root systems of corn and sorghums show that corn possesses about one-half the secondary roots and about twice the leaf surface of sorghum, enabling the latter to withstand reduction in soil moisture with less injury. It is known that corn plants differ markedly in their root systems. Plants of pure lines with finer, more branched root systems should be able to absorb more water. By measuring the roots it might be possible to find a correlation with drouth resistance.

Although several of the susceptible lines studied had root systems of small volume, one of the susceptible lines had the largest total weight of roots of the 20 tested. This strain, however, fires severely in the upper leaves. The character of the root system may partially account for susceptibility to drouth in those strains but not in all of them. With so many exceptions, a study of the root system of unknown strains could not be used as an index of their drouth resistance or susceptibility.

Since the roots of the corn plant arise from the nodes and since root primordia are present at each node but develop for the most part at the nodes below the surface of the soil, it was thought that the number of nodes in the soil would influence the extent of the root system. This in turn might be a limiting factor in determining the extent of injury which might occur under drouth conditions. The number of nodes below the soil surface of 21 pure lines of sweet corn was counted. Results are presented in table 6. The number of nodes below the surface of the soil did not differ in susceptible and resistant lines.

Dr. A. A. Bryan, of the Farm Crops Subsection of the Iowa Agricultural Experiment Station, has called the writer's attention to a pure line of field corn isolated by Dr. Jenkins, called rootless.

TABLE 6. NUMBER OF NODES BELOW SOIL SURFACE OF INBRED SWEET CORN LINES.

Resistant	No. of nodes	Susceptible	No. of nodes
1445	6.0	157	6.0
1612	5.5	701	5.0
1621	6.0	1126	5.5
191	5.0	1071	6.0
123	4.5	1214	5.0
777	4.5	900	5.0
261	5.0	1627	5.5
1284	5.0	1607	5.0
853	5.5	1448	5.0
908	5.0	1572	5.0
		1608	4.0
Mean	5.2	Mean	5.2

The root system is so poor that staking of plants is necessary to prevent breaking off at the surface of the soil. In spite of a weak root system, this line is rated by Dr. Bryan as fairly resistant to drouth.

VASCULAR BUNDLES

Leaves are dependent for their water supply on the conduction of water through the vascular system from the roots. It might be supposed that the extent of the vascular system, that is, the number of bundles in the stalk, might govern the amount of water which could be conducted to the leaves. A number of plants of inbred lines were grown in the greenhouse during a 2-year period. The number of bundles in individual stalks was counted by the use of free-hand cross-sections of the stems. Thin sections were placed on a glass slide and stained as follows: Tissue was covered with a 5 percent solution of phloroglucinol in absolute alcohol. The excess solution was blotted from the tissue with blotting paper, then a 50 percent solution of HCl was applied to the tissue and the excess blotted off. The walls of the bundles are stained red by this method and are easily distinguished for counting with a low power microscopic lens. The total number of bundles in the stem was counted and the number was found to be directly correlated with the size of the stem. This agrees with the conclusions of Martin and Hershey (13). Since the number of vascular bundles is greater in the larger stems of plants within the same "pure" line, the number of bundles per square millimeter of cross-section was figured. The stem area was calculated using the formula, πab, for the area of an ellipse, because many of the stems are not round, differing frequently as much as 4 millimeters in the diameters measured at right angles to each other. This may not be a highly accurate measurement. Besides, the bundles are far more numerous in the outer portions of the cross-section than in the inner portions so that figures given may not represent the number of bundles found in each individual square millimeter, but they are an average of the entire cross-section.

Five resistant and five susceptible inbreds were grown in the greenhouse in each of two media, compost and a very sandy soil of low fertility, to influence the size of the stalks. The plants in sandy soil developed stems of smaller diameter than plants of the same line grown in compost. Results of the examination of 69 plants are given in table 7.

The analysis of variance applies only to the figures given for the average number of bundles per square millimeter. There were no significant differences except between inbreds within the groups, i.e., the individuals, susceptible or resistant, differed significantly between themselves, but the two groups did not. Likewise the fertility of the soil did not bring out significant differences in

TABLE 7. VASCULAR BUNDLES IN RESISTANT AND SUSCEPTIBLE SWEET CORN INBRED LINES.

Compost					
Susceptible			Resistant		
Inbred	Total no. bundles in cross-section	Ave. no. bundles per sq. mm.	Inbred	Total no. bundles in cross-section	Ave. no. bundles per sq. mm.
1607	303	5.42	191	261	3.97
1608	297	4.42	777	207	4.38
1627	369	4.95	1445	359	5.24
900	347	3.91	1610	413	6.02
1572	248	4.63	1612	371	3.84
Mean	313	4.66	Mean	322	4.69
Sandy soil of low fertility					
1607	277	5.04	191	232	4.09
1608	277	6.72	777	217	3.83
1627	305	6.15	1445	359	5.24
900	378	3.04	1610	400	5.67
1572	265	3.55	1612	334	4.16
Mean	300	4.90	Mean	308	4.60

Analysis of variance of average number of bundles per square millimeter.

Source of variation	Degrees of freedom	Mean square
Resistant vs. susceptible	1	3279.18
Media in the same group	2	1782.63
Inbreds of same group and medium	16	16983.30**
Plants of same inbred on same medium	49	1687.47
Total	68	

**Highly significant

average number of bundles per square millimeter, although it did affect the diameter of the stalks of the plants of the same pure line.

From observation it was noted that field corn inbreds are generally more resistant to drouth than sweet corn inbreds. Dr. Bryan furnished seed of field corn lines classified by him as resistant or susceptible to drouth. These were grown in compost and in soil of low fertility. Counts were made of the bundles in 44 plants with a procedure similar to that given for the sweet corn inbreds. Results are presented in table 8. The group of susceptible inbreds had a significantly greater number of bundles per square millimeter than resistant lines, irrespective of medium. High or low fertility had no effect, but the inbreds within a group differed from each other.

Since the field corn lines showed a difference, a limited number of sweet corn inbreds were grown again. Only those inbreds exhibiting a high degree of resistance or susceptibility were included. Since media had no effect in the two previous tests, soil of average fertility was used to grow the plants. The same procedure and methods for counting were used as before. Results are presented in table 9. Again there are no significant differences except among the inbreds within the group.

Plants of susceptible and resistant lines were grown again in the greenhouse in the fall of 1937. The plants were subjected to more

TABLE 8. VASCULAR BUNDLES IN RESISTANT AND SUSCEPTIBLE FIELD CORN INBRED LINES.

Compost					
Susceptible			Resistant		
Inbred	Total no. bundles in cross-section	Ave. no. bundles per sq. mm.	Inbred	Total no. bundles in cross-section	Ave. no. bundles per sq. mm.
CL 447A2	216	1.64	Mc 401	233	1.01
I 242	280	1.17	I 154	229	1.09
I 233	246	1.97	Bl 345B	331	1.47
			L 317B2	300	0.95
Mean	247	1.59	Mean	273	1.13
Sandy soil of low fertility					
Cl 447A2	173	1.64	Mc 401	203	1.27
I 242	268	1.23	I 154	217	1.27
I 233	254	1.94	Bl 345B	336	1.43
			L 317B2	290	0.94
Mean	232	1.60	Mean	261	1.23

Analysis of variance of average number of bundles per square millimeter

Source of variation	Degrees of freedom	Mean square
Resistant vs. susceptible	1	2.4515**
Media in the same group	2	.0814
Inbreds of same group and medium	10	.2349**
Plants of same inbred on same medium	30	.0452
Total	43	

**Highly significant

severe treatment than any previously used. The plants were not watered after they were about 1 foot high until slight wilting occurred. Only a small amount of water was applied. No more was applied until slight wilting reoccurred. When the tassels appeared, vascular bundles were counted in 6 to 12 plants in each line or a total of 123 plants. It was thought that with more severe conditions and with counts made of a great number of plants in each line, differences might occur which were significant. Such was not the case. Results are presented in table 10. Only inbreds irrespective of classification differed significantly.

TABLE 9. NUMBER OF VASCULAR BUNDLES IN HIGHLY RESISTANT AND SUSCEPTIBLE SWEET CORN LINES.

Resistant	Total no. bundles in stalk	Ave. no. bundles per sq. mm.	Susceptible	Total no. bundles in stalk	Ave. no. bundles per sq. mm.
777	313	3.27	900	268	3.79
1445	376	4.35	1608	222	3.49
			1448	291	3.33
Mean	344	3.81	1214	199	3.95
			1071	348	4.68
			Mean	266	3.85

Analysis of variance of average number of bundles per square millimeter

Source of variation	Degrees of freedom	Mean square
Resistant vs. susceptible	1	.0323
Inbreds in groups	5	1.2624**
Plants of same inbred	20	.0687
Total	26	

**Highly significant

TABLE 10. NUMBER OF VASCULAR BUNDLES IN PLANTS GROWN IN THE GREENHOUSE IN THE FALL OF 1937.

Inbred number	Total number of bundles	Average number of bundles per sq. mm.
Resistant		
317	437	3.04
13	360	4.71
1445	485	3.38
1612	454	2.67
Mean	434	3.59
Susceptible		
1627	470	3.46
1071	581	3.44
1608	389	3.08
2306	453	5.06
2091	404	3.73
1363	417	3.51
Mean	452	3.71

Analysis of variance of average number of bundles per square millimeter

Source of variation	Degrees of freedom	Mean square
Resistant vs. susceptible	1	.0505
Inbreds in the groups	8	4.2714**
Plants of same inbred	113	.2391
Total	122	

**Highly significant

As stated before, in late July, 1937, during a comparatively favorable season for growth of corn, several "pure lines" fired. Four of these lines were grown in the greenhouse in the fall of 1937 together with one "pure line" which is highly drouth and heat resistant. When the plants were nearing the tassel stage, they were placed in a warm room with a temperature of 90°F and water withheld. The relative humidity of the air was about 25 percent. The sudden change from favorable growing conditions to unfavorable conditions, high temperature and low humidity, produced to a small degree symptoms resembling those obtained in the field under drouth conditions, i.e., inbred lines, 1071 and 2306, which show firing of top leaves in the field, showed slight withering of those leaves in the laboratory, and inbred lines, 2091 and 1627, which fire badly in the lower leaves, also exhibited withering of lower leaves in the laboratory (table 11).

Vascular bundle counts were made of individual plants at or near each node from the first node above ground to the node just below the tassel. The figures given in table 11 are averages of the counts made on four plants in each inbred line. Plants were selected for these counts having approximately the same diameter of stalks for all lines inasmuch as the number of bundles increases with the diameter of stalk even within the same line.

Inbred lines, 2091 and 1627, which exhibited firing, had fewer vascular bundles at the lower five or six nodes than the normal inbred line 1445 which had not fired, and the lines 1071 and 2306

TABLE 11. NUMBER OF VASCULAR BUNDLES IN EACH NODE OF FIVE DIFFERENT INBRED LINES OF SWEET CORN.

Node	N 1445	T 1071	T 2306	B 2091	B 1627
1	465	571	502	345	342
2	506	561	538	381	364
3	513	555	543	402	371
4	501	557	535	394	382
5	485	514	529	387	381
6	429	466	476	335	352
7	376	386	401	275	321
8	297	310	355	232	307
9	271	250	300	198	249
10	258	202	270	168	228
11	235	157	250	159	176
12	190	117	213		171
13			211		170

N, no leaves show firing
T, top leaves from ninth to twelfth node fired
B, bottom leaves from first to fifth node fired

which fired only in the upper leaves. The reduced number of bundles may account for firing of lower leaves. Lines 1071 and 2306, however, showed no marked difference in number of bundles from the check, 1445. The rapid growth rate of the upper leaves, because of favorable growing conditions, may render them susceptible to damage when climatic changes occur suddenly, such as a rapid rise in temperature, lowering of the relative humidity of the air and reduction in soil moisture supply. Inbred lines which do not fire in the upper leaves may have a slower growth rate at that point, and are, therefore, less susceptible to damage from sudden changes in climate. Because of the limited number of lines used, it is doubtful whether firing of lower leaves can be attributed to reduced number of bundles, since no differences are reported in other tables from the same and similar lines.

In the studies reported here, the plants of strains for comparison were grown in environmental conditions as nearly alike as was possible under greenhouse conditions. Counts made on stalks of sweet corn inbreds did not differ significantly between resistant and susceptible strains. Counts made with a fewer number of pure lines of field corn showed a significant difference between the groups of resistant and susceptible strains. Resistant lines had fewer bundles per unit area than the susceptible, which may be contrary to what one might expect. Fewer numbers should diminish the volume of water which might be conducted to the leaves under dry, hot conditions causing greater injury to the leaves; this theory of course assumes that the transpiration rate would be equal in both groups. Plants of the same strain grown in rich soil or poor soil did not differ significantly in average number of bundles per unit cross-section of stem, although there were fewer bundles in the stalks of plants on the poor soil, because the stalks were smaller. The poor soil had less water holding capacity, but injury caused by drouth occurred alike in both soils when there was sufficient reduction in available soil moisture. Injury occurred sooner in the sandy soil of poor fertility, but only because the water holding capacity was less than in the compost.

EFFECT OF HIGH TEMPERATURES ON SEEDLINGS

Hunter, Laude and Brunson (8) suggested a method for testing corn seedlings for drouth and heat resistance by exposure to 140°F for 6.5 hours. When this was tried with sweet corn inbred lines there were no survivors. Dr. Bryan furnished inbred field corn lines, classified as resistant and susceptible to drouth; very few plants in his resistant lines survived the treatment suggested by the above workers. Since conditions are usually less favorable for the growth of corn in Kansas than in Iowa, it may be that the Kansas corn breeders have developed, through selection, inbred lines of field corn which are more resistant to heat and drouth than most of the lines developed in Iowa.

Seeds of inbred lines of sweet corn and field corn were planted in 4 or 5-inch pots and the seedlings grown in the greenhouse until 15 to 20 days old. The seedlings were then exposed to varying high temperatures for varying lengths of time to discover, if possible, if

TABLE 12. SURVIVALS OF SWEET CORN SEEDLINGS EXPOSED TO 55°C. (131°F.) FOR VARIOUS INTERVALS.**

Inbred	Reaction	Time of exposure (hours)	No. of plants tested	No. of survivals	Percent survivals
		4	76	69	90.8
1445	N	5	62	47	75.8
		6	48	39	81.2
		4	52	52	100.0
1612	N	5	40	32	80.0
		6	29	9	31.0
		4	56	55	98.2
1071	T	5	47	23	48.9
		6	36	0	0.0
		4	109	47	43.1
1627	B	5	64	14	21.9
		6	39	0	0.0
		4	88	56	63.6
900	T	5	47	2	4.3
		6	37	0	0.0
2306	T	5	54	2	3.7
		6	31	0	0.0
2091	B	5	57	19	33.3
		6	28	0	0.0
		4	31	29	93.5
*LDG317	N	5	27	27	100.0
		6	14	11	78.6
13	N	6	41	35	85.4
1363	T	6	27	14	51.8
1608	HS	5	42	0	0.0
1607	HS	5	29	0	0.0
191	N	6	36	18	50.0
1804	HS	5	18	0	0.0
1448	B	6	19	0	0.0
*Mc401	N	6	15	15	100.0
*I-233	T	6	18	10	55.5

*Field corn

**In the second column, captioned "reaction," the letters used designate the classification based on field readings.

N, lines showing no firing.

T, lines showing firing of upper leaves.

B, lines showing firing of lower leaves.

HS, lines showing extreme rolling of leaves and stunting of plants.

TABLE 13. SURVIVALS OF SWEET-CORN SEEDLINGS OF DIFFERENT AGES EXPOSED TO 55°C. (131°F.) FOR 5 HOURS.

	1071		1612	
Age of seedlings in days	Number tested	Number survivals	Number tested	Number survivals
15	14	7	16	15
17	12	10	12	12
19	8	6	11	11
21	8	5	10	7
23	8	4	7	7
25	16	1	8	4
27	11	1	7	4
29	8	0	11	3

there was a definite temperature and a definite exposure to that temperature, the reaction to which would classify sweet corn inbred lines as drouth and heat resistant or susceptible. After the plants were removed from the oven they were watered, placed in the greenhouse for 1 week, and then counts were made on the number of plants which had survived in each line.

Exposure to 55°C (131°F) for 5 hours caused the death of most of the seedlings of the susceptible lines. Even when exposed only 4 hours, highly susceptible lines, such as 900, 1607, 1608 and 1804 showed very few or no survivors. Most of the resistant lines showed a high percentage of survivors at 5 hours and a few, including two resistant field corn lines, at 6 hours. Results are presented in table 12.

For purposes of comparison, it is essential, when the "oven" test is used, that seedlings of all lines be approximately of the same age. Different readings may be expected from the same line at different ages. In table 13 are presented the results obtained when the seedlings of one resistant line, 1612, and one susceptible line, 1071, which top-fires, were exposed at different ages to 55°C for 5 hours. The youngest seedlings were 15 days old. Tests were made at 2-day intervals, until the seedlings were 29 days old. Older seedlings in both lines showed fewer survivors than the younger seedlings.

Testing by subjecting seedlings to heat seems to offer a promising method of classifying the lines. Although 1 week elapsed from the time of treating the plants until readings on mortality were taken, it was possible after a few tests to distinguish on removal from the oven the plants which would survive. Susceptible plants wilted much more than plants of resistant lines. Resistant sweet corn pure lines or strains will not withstand the same degree of heat and drouth as pure lines of field corn; this is discernible both in the field and in the oven test. This difference may be accounted for in the greater vigor of the field corn lines. Likewise, most sweet corn hybrids are more resistant to heat and drouth than most pure lines of sweet corn; also later (in season) maturing, vigorous lines of sweet corn are generally more resistant than earlier less vigorous lines, although this is not always true.

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